Europäisches Patentamt

European Patent Office

Office européen des brevets

(11) Publication number: **0 397 377 A1**

EUROPEAN PATENT APPLICATION

(21) Application number: 90304751.2

(51) Int. Cl.⁵: **A61B 3/12**

(22) Date of filing: 02.05.90

(30) Priority: 08.05.89 JP 113664/89

(43) Date of publication of application:
14.11.90 Bulletin 90/46

(84) Designated Contracting States:
CH DE FR GB IT LI

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(54) Method and apparatus for discriminating eye fundus blood vessels.

(57) Light beams of different predetermined wavelengths (12a, 13a) are projected into the eye fundus and light scattered therefrom is detected (19, 20) to distinguish blood vessels from surrounding tissues in the eye fundus by taking advantage of differences in the light absorbing/reflecting characteristics of the fundus blood vessels and surrounding tissues.
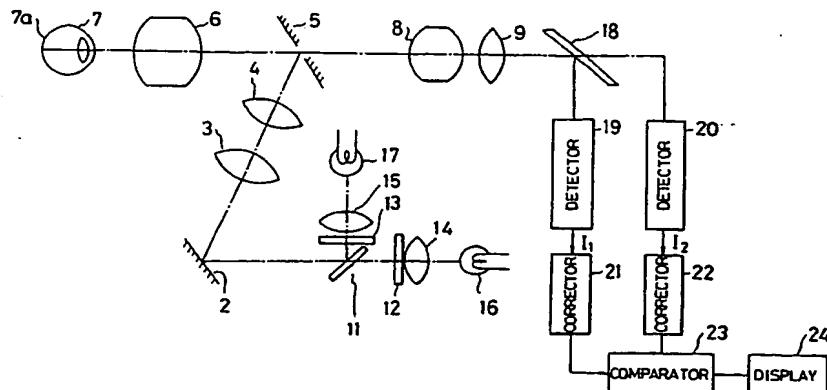
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F I G. 1

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a method and apparatus for discriminating eye fundus blood vessels, and more particularly to a method and apparatus for discriminating eye fundus blood vessels in which a light beam of prescribed wavelength is projected into the eye fundus and light scattered therefrom is detected to distinguish a blood vessel in the eye fundus.

Description of the Prior Art

In typical ophthalmological apparatuses such as optical coagulators or eye fundus blood veloci-meters, a prescribed beam of monochromatic co-herent light is projected to a region in the eye fundus and light scattered therefrom is detected to discriminate fundus blood vessels in order to rec-ognize whether an eye being examined is moving or immobile. There are also methods and ap-paratuses for obtaining color images of the eye fundus by scanning the eye fundus with light which includes the wavelength regions of the three pri-mary colors, red (R), green (G) and blue (B), and discriminating fundus blood vessels by receiving the light thereby scattered by the eye fundus.

A drawback of systems based on the use of monochromatic light is that, during the examination procedure, any deviation in the alignment between the patient and the apparatus will change the quan-tity of scattered light that is detected, resulting in erroneous blood-vessel recognition. With ap-paratuses which project multi-chromatic light such as RGB light, for example, onto the eye fundus and detect and convert the scattered light from the eye fundus to obtain an image signal which is used to identify a blood vessel, attention must be paid to the fact that light absorbing and reflecting char-acteristics of the fundus blood vessels and sur-rounding tissues differ depending on the wavelength of the light concerned. This fact is not fully recognized, so that the signal obtained from the scattered light has a poor signal-to-noise (S/N) ratio which gives rise to erroneous blood-vessel recognition.

SUMMARY OF THE INVENTION

An object of the present invention is therefore to provide a method and apparatus for discriminat-ing eye fundus blood vessels which makes full use of differences in the light absorbing reflecting char-acteristics in fundus blood vessels and surrounding tissues and is therefore able to reliably discriminate fundus blood vessels without error even if there is a shift in the alignment between the apparatus and the eye.

In accordance with the present invention the above object is attained by means of an arrange-ment for discriminating eye fundus blood vessels, comprising the steps of projecting light having first and second wavelengths into the eye fundus, ob-taining the difference, ratio, or the common loga-rithm of the ratio between the quantity of scattered light of the first and second wavelengths from the fundus blood vessel and surrounding tissue, and comparing the value thus obtained with a pre-scribed value.

The principle on which this arrangement is based, taking the example of red blood cells in a blood vessel of the eye fundus, is that blood cells, oxygenated or deoxygenated, have a higher reflec-tance to light with a wavelength in the range 600-660 nm than light with a wavelength in the 560-580 nm range, and a higher absorbance of light with a wavelength in the 560-580 nm range than light with a wavelength in the 600-660 nm range, while on the other hand, if the light is scattered by surround-ing tissue, the above relationships will oe reversed. Thus the present invention employs an arrange-ment comprising the steps of projecting light of two different wavelengths onto the eye fundus and de-tecting light scattered by blood vessel and sur-rounding tissue, converting this detected light into electrical signals and obtaining the difference, ratio, or the common logarithm of the ratio between the quantity of scattered light of the first and second wavelengths from the fundus blood vessel and sur-rounding tissue.

The arrangement of this invention fully utilizes the fact that light absorbing and light reflecting characteristics of fundus blood vessels and sur-rounding tissues depends on the wavelength of the light concerned, and enables fundus blood vessels to be reliably discriminated.

BRIEF DESCRIPTION OF THE DRAWINGS

The purpose and features of the present inven-tion will become more apparent from a consider-ation of the following detailed description taken in conjunction with the accompanying drawings in which:

Figure 1 is a drawing showing the general arrangement of an apparatus according to one em-bodiment of the invention;

Figure 2 shows characteristic curves of inter-ference filters;

Figure 3 shows a characteristic curve of a

wavelength separation mirror;

Figure 4 shows the light reflecting and absorbing characteristics of blood vessel tissue;

Figure 5 shows the light reflecting and absorbing characteristics of surrounding tissue; and

Figure 6 is a drawing showing the arrangement of a detector which uses a photosensor device other than an imaging element.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is described in detail below on the basis of the preferred embodiments illustrated in the drawings.

With reference to Figure 1 which shows the general arrangement of one embodiment of the apparatus of the invention, light from light sources 16 and 17 passes through condenser lenses 14 and 15 and interference filters 12 and 13 and is combined by a wavelength separation mirror 11. As illustrated by Figure 2a, interference filter 13 has a peak at around 580 nm, while interference filter 12, as shown in Figure 2b, has a peak at around 660 nm. The characteristics of the wavelength separation mirror 11 are shown in Figure 3, showing that the reflectance of the mirror changes sharply in the 580-600 nm region. The wavelength separation mirror 11 combines light that passes through the interference filters 12 and 13, and therefore passes light with a 580 nm peak and light with a 660 nm peak.

The light is then reflected by a mirror 2 whereby it is directed through relay lenses 3 and 4 and is reflected by an annular mirror 5 and passes through an objective lens 6 and impinges onto a region in the fundus 7a of the subject's eye 7.

Scattered light from the eye fundus 7a passes back through the objective lens 6 and annular mirror 5, a focusing lens 8 and an image forming lens 9 and impinges on a wavelength separation mirror 18, which has the characteristics shown in Figure 3. Light reflected by the wavelength separation mirror 18 will be light that has a 580 nm peak, and this light is taken to a light intensity detector 19 constituted by an imaging device, for example. Light passed by the mirror 18 will be light which has a 660 nm peak, and this light is likewise taken to a light intensity detector 20 constituted by an imaging device or the like.

Signals from the light intensity detectors 19 and 20 are input to correctors 21 and 22 and corrected, and are then compared by a signal comparator 23. A display 24 is used to show whether the light from the eye fundus was scattered by a blood vessel or light scattered by surrounding tissue.

The operation of the apparatus thus arranged will now be described.

Red blood cells in a blood vessel of an eye fundus will normally have the type of reflectance characteristics shown in Figure 4a, differing each side of a 590 nm center. As shown in Figure 4b light absorption of both deoxygenated and oxygenated blood cells peaks at around 580 nm. The reflectance and absorption characteristics of the surrounding tissue are shown in Figure 5, showing that as the wavelength of the light increases, there is a fall-off in both reflectance and absorption.

Therefore, blood cells, oxygenated or deoxygenated, in a blood vessel in the eye fundus will reflect more light with a wavelength in the range 600-660 nm than light with a wavelength in the 560-580 nm range, and will absorb more light with a wavelength in the 560-580 nm range than light with a wavelength in the 600-660 nm range. On the other hand, surrounding tissue will reflect more light with a wavelength in the range 560-580 nm than light with a wavelength in the 600-660 nm range, and will absorb more light with a wavelength in the 600-660 nm range than light with a wavelength in the 560-580 nm range.

Therefore, if the intensity of scattered light with a wavelength in the 560-580 nm range is $I1$ and the intensity of scattered light with a wavelength in the 600-660 nm range is $I2$, in the case of a blood vessel

$$I1 - \alpha I2 < 0 \qquad (1)$$

and in the case of surrounding tissue

$$I1 - \alpha I2 > 0 \qquad (2)$$

Using a common logarithm to obtain the intensity ratio of the beams of scattered light gives

$$\log(I1/\alpha I2) < 0 \qquad (3)$$

in the case of a blood vessel, and

$$\log(I1/\alpha I2) > \qquad (4)$$

in the case of surrounding tissue. Here, α is a correction coefficient, which will be described below.

Based on this principle, when scattered light from the eye fundus is divided by the wavelength separation mirror 18, scattered light with a wavelength of around 580 nm is input to the detector 19 and light with a wavelength of around 650 nm is input to the detector 20, whereby signals of intensities $I1$ and $I2$ are obtained from the respective detectors.

Because the amount of light with a wavelength in the 560-580 nm range will be different from the amount of light with a wavelength in the 600-660 nm range, and also because the detector sensitivity is wavelength dependent, the signal intensities detected by the detectors 19 and 20 in the case of an actual apparatus may not have the relationships illustrated by Figures 4 and 5, so a correction coefficient α is applied to the signal level. For this, the signals from the detectors 19 and 20 are input

to the correctors 20 and 21.

To effect blood vessel discrimination using the differences in the intensities of scattered light in the 560-580 nm and 600-680 nm range, a correction coefficient α must be selected that will ensure the equations (1) and (2) hold. For example, a correction coefficient could be used which would ensure that the signal level produced by the detector 19 which detects 580 nm light from blood vessel tissue is lower than that of the detector 20 which detects 650 nm light. This is determined by the ratio of light passed by the filters 12 and 13.

Signals from the correctors 21 and 22 are input into the signal comparator 23, where they are processed to extract the difference therebetween or the ratio of one to the other. To obtain the difference, the signals are binarized as plus or minus, i.e., in accordance with (1) or (2). To obtain the ratio, they are binarized as 1 or less or less than 1. On the basis of the binarized signals, the display 24 displays whether the illuminated region is a blood vessel or surrounding tissue.

When an imaging element is used as the detectors 19 and 20, the display 24 can display a digitized image of the blood vessel, and it is also possible for the diameter of the blood vessel to be displayed.

It goes without saying that if a scanning fundus camera is used to obtain image information from the intensities of the scattered light, the detectors 19 and 20 need not be imaging elements.

Instead of an imaging element, an arrangement may be used such as the one shown in Figure 6 in which a unit formed of a pinhole aperture 25 and detector 26 and a pinhole aperture 27 and detector 28 is positioned so that the pinhole apertures 25 and 27 are conjugate with the eye fundus. With this arrangement it becomes possible to determine whether the point on the eye fundus conjugate with the pinhole apertures 25 and 27 is or is not a blood vessel.

The embodiment described above shows the eye fundus blood vessel discrimination apparatus as modular, but it could be integrated into an actual ophthalmic apparatus with slight modifications without departing from the scope of the invention.

Claims

1. A method for discriminating eye fundus blood vessels in which a light beam of predetermined wavelength is projected into the eye fundus and light scattered therefrom is detected to distinguish blood vessels in the eye fundus, charaterized in that light of predetermined first and second wavelengths (12, 13, 16, 17) is projected onto an eye fundus (7a), that first and second wavelength light scattered from fundus blood vessels and surrounding tissue are seperately detected (19, 20), and that the difference or the ratio, or the common logarithm of the ratio between the detected light beams of the first and second wavelengths is calculated and compared (23) with a predetermined value to distinguish the blood vessels from surrounding tissues.

2. The method according to claim 1, wherein the scattered light is imaged and detected at an image plane that is conjugate with the eye fundus.

3. The method according to claim 1, wherein the projected light scans the eye fundus (7a).

4. The method according to any of claims 1 to 3, wherein the first wavelength light has a predetermined wavelength selected from the range 560 nm to 580 nm (13a) and the second wavelength light has a predetermined wavelength selected from the range 600 nm to 660 nm (12a).

5. An apparatus for discriminating eye fundus blood vessels in which a light beam of predetermined wavelength is projected into the eye fundus and light scattered therefrom is detected to distinguish blood vessels in the eye fundus, characterized by:
means (12, 13, 16, 17) for projecting first and second wavelength light into an eye fundus;
means (16, 20) for separately detecting first wavelength scattered light from the eye fundus and second wavelength scattered light from the eye fundus; and
means (23) for calculating the difference or the ratio, or the common logarithm of the ratio between signals of each wavelength from the detector means;
whereby the blood vessels are discriminated from surrounding tissues on the basis of the results of the calculation.

6. The apparatus according to claim 5, wherein the scattered light is imaged and detected at an image plane that is conjugate with the eye fundus (7a).

7. The apparatus according to claim 5, wherein the projected light scans the eye fundus (7a).

8. The apparatus according to any of claims 5 to 7, wherein the first wavelength light has a predetermined wavelength selected from the range 560 nm to 580 nm (13a) and the second wavelength light has a predetermined wavelength selected from the range 600 nm to 660 nm (12a).

9. The apparatus according to any of claims 5 to 8, further comprising correction means (21, 22) for correcting values of signals at each wavelength received from the detection means.

FIG. 1

FIG. 2a

TRANSMISSION FACTOR

13a

560 580 600
WAVELENGTH(nm)

FIG. 2b

TRANSMISSION FACTOR

12a

640 660 680
WAVELENGTH(nm)

FIG. 3

REFLECTANCE

580 660
WAVELENGTH(nm)

FIG. 4a

REFLECTANCE

500 580 (590) 650
WAVELENGTH(nm)

FIG. 4b

ABSORPTION

580 650
WAVELENGTH(nm)
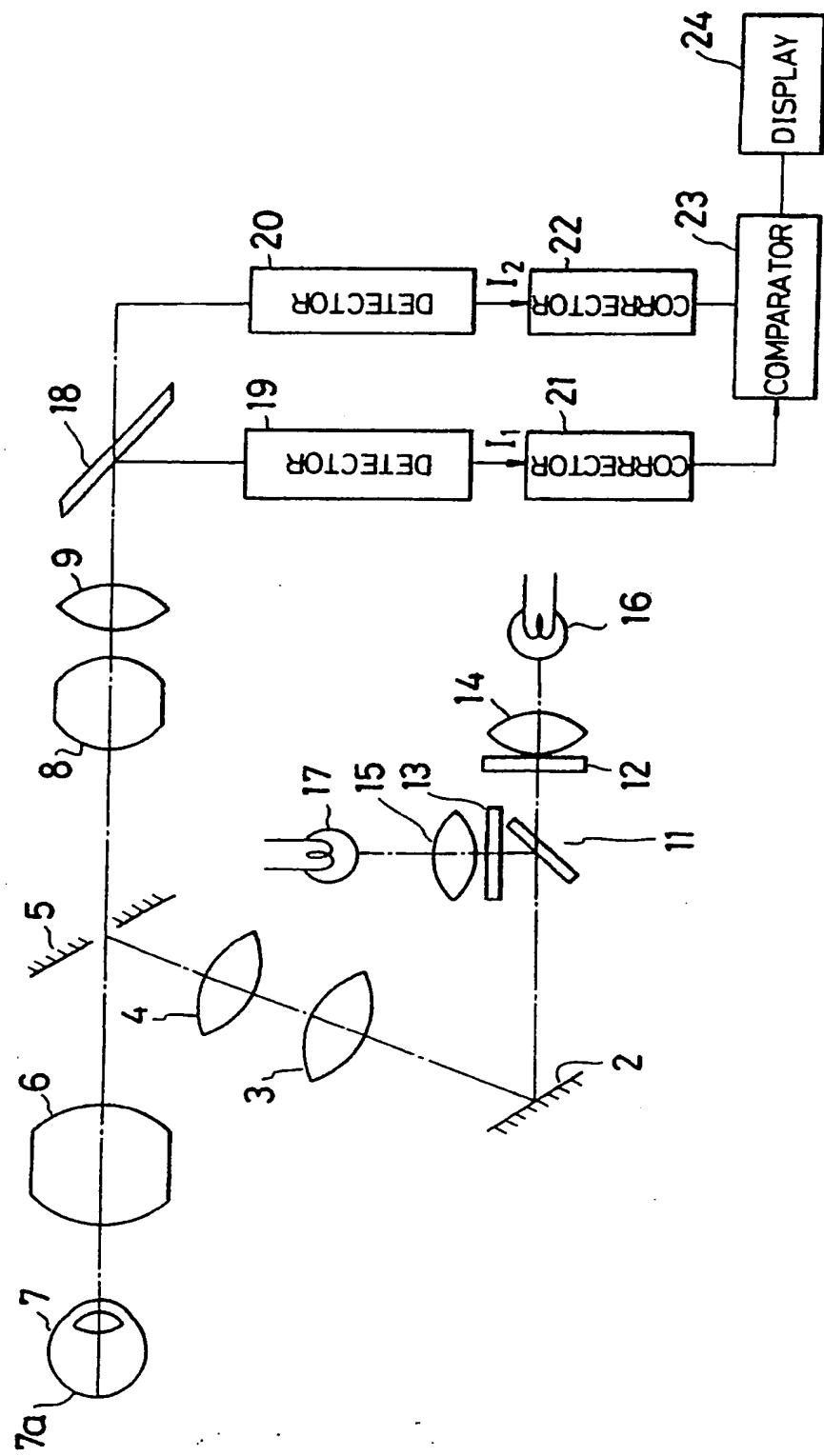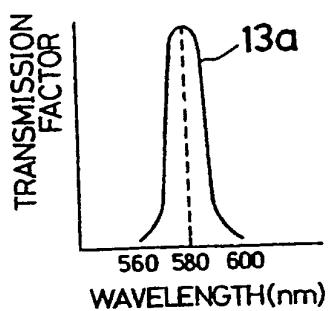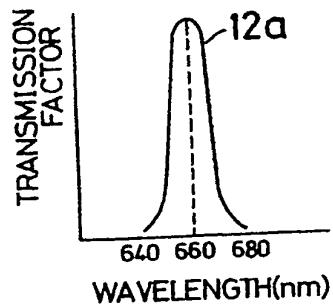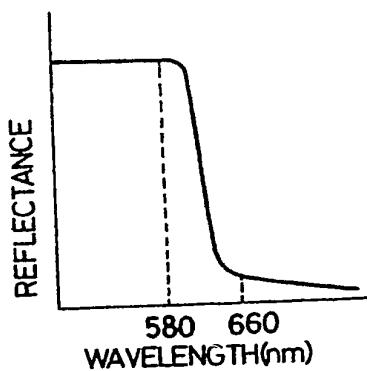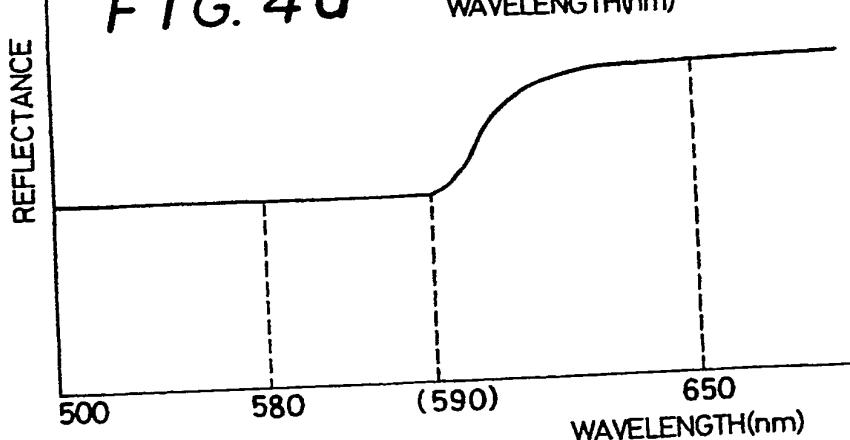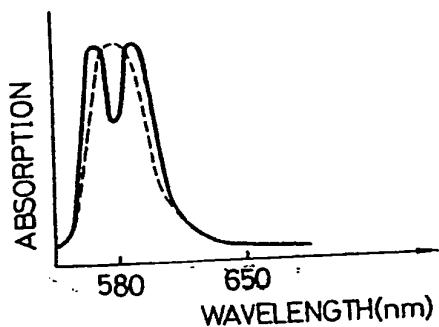
FIG. 5 a
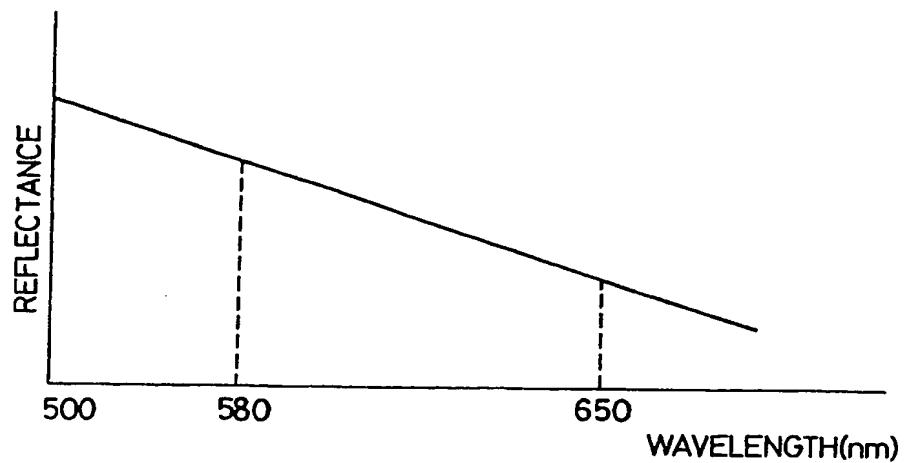
FIG. 5 b
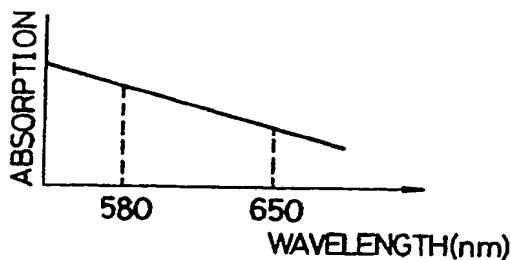
FIG. 6
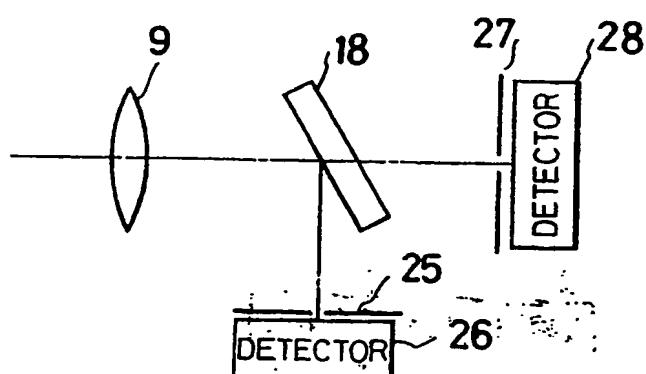
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EUROPEAN SEARCH REPORT

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	DE-A-2645340 (MINOLTA CAMERA K.K.) * page 5, line 5 - page 6, line 13 * * page 11, line 9 - page 14, line 25 * * claims 1, 2; figures *	1, 4, 5, 8	A61B3/12
X	US-A-4305398 (S. SAWA) * column 2, lines 1 - 45; figures * * column 4, line 5 - column 5, line 25 *	1, 2, 5, 6, 9	
X	IEEE TRANSACTIONS ON BIO-MEDICAL ELECTRONICS. vol. BME22, no. 3, May 1975, NEW YORK US pages 183 - 195; R.A. LAING et al.: "The Choroidal Eye Oximeter: An Instrument for Measuring Oxygen Saturation of Choroidal Blood In Vivo" * pages 188 - 191; figures 6, 7, 10, 12 *	1, 5, 9	
A	FR-A-2537428 (CARL ZEISS) * page 8, lines 5 - 14 * * page 17, lines 5 - 34; figures *	1-8	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	FR-A-2615723 (TOKYO KOGAKU KIKAI K.K.) * page 7, line 3 - page 10, line 22; figures *	1-3, 5-7	A61B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	10 JULY 1990	RIEB K.D.

EPO FORM 1503 03.82 (P0401)

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